INTERFERENCES BETWEEN PHYSICAL EXERTION AND DIFFERENT STAGES OF INFORMATION PROCESSING

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INTRODUCTION

One of the main factors of motor performance consisted for subjects in the capacity to process information rapidly and accurately, particularly during physical exercise. Many examples were known in sports where subjects, submitted to high time-pressure had to perceive, decide and move with efficacy despite a severe physical exertion.

Many experiments have examined the influence of physical exercise on cognitive performance but the results showed mostly inconsistency. In a review of literature, Tomporowski and Ellis (1986) revealed that most conflicting results may be due to a wide variety of methodological approaches. So, the nature of physical protocols was very important, especially when subjects had different physical fitness (Brisswalter, Legros & Delignières 1994).

Likewise, in the aim of controlling cognitive tasks, recent studies used classic mental chronometric procedures (Pass & Adam, 1991). An appropriate reading of experiments in this paradigm showed contrasting effects of physical exertion according to the nature of cognitive processes, particularly when the reaction time task takes place during physical exercise (Delignières, Brisswalter & Legros, 1994; Legros, Delignières, Durand & Brisswalter, 1992). Generally, these studies showed an impairment of the performance in simple reaction time paradigm and a contrario, only for specialist of decisional activities, an improvement in choice reaction time paradigm. Nevertheless, more exceptional were experiments that focused on this comparison between one of perceptual or decisional stages and the motor side of information processing.

1. This experiment had been performed at the University Hospital Center, Angers, in the Functional Explorations service. The students came from the Formation Institute of Physical Education and Sports of Angers. We thank these two institutes for their contribution to this experiment.
Most of research which tried to find the locus of effect of an energetical variable in the sequence of information processing used the Additive Factors Method (from Sternberg, 1969). This method suggested that when two variables (energetical vs cognitive) interact they had direct influences on the same processing structures. In addition, in keeping with Sanders (1983) the effect of indirect energetical variable widely fluctuated between individual trials and, hence, affected the end of reaction time distribution.

The aim of the present study was to compare the interferences of physical exercise on two information processing stages, the response choice and the motor adjustment stages (Sanders, 1990). We expected to observe on the two processing stages, a differentiated effect of physical exertion more than a general one. In this case, the effects of exertion would be mainly located at the highest end of the reaction time distribution, specially on the third quartile value.

**METHOD**

Twelve females and twelve males participated as subjects. They were students in physical education, volunteers and had normal or corrected to normal vision. All were non-experts in sports which required a decisional activity (as team or combat sports). Their mean age was 25.4 years (s.d.-6.95) for the males and 21.58 years (s.d.-1.68) for the females. In a preliminary protocol (adapted from Storer, 1990) subjects were submitted to individually determined maximal oxygen uptake (VO2 max., in ml.min⁻¹.kg⁻¹) and maximal power attained with VO2 max. (Pmax, in watts). Mean VO2 max. and mean Pmax. values were in respective, 59.95 (s.d.=10.48) and 360 (s.d.-28.06) for the males and 47.67 (s.d.-3.70) and 257.50 (s.d.-15.75) for the females.

Both, in preliminary exercises and experimental protocols, a cycloergometer Miditronic was used. A screen displaying the number of revolutions per minute was positioned in front of subject to provide with feedback regarding pedalling rate. Heart rate was measured in continuous with a Sport tester PE 3000 system (Polar). In the aim of maximal standardization of protocols, the experimental device could be adapted to the morphology of each subject and the luminosity, the heat (Delignières & Brisswalter, this volume) and the moistness were controlled.

The reaction time (RT) tasks were performed by using a computer connected with two joysticks, held in front of the ergometer handlebar. For more conveniences, the forearms of the subject were placed on elbow-rests and the joysticks were pressed only with the thumb. Subjects had to decide as fast as possible on the computer screen, which of the two response signals was the most appropriate by tilting on the appropriate joystick.

Subjects were required to respond to a visual two-choice RT task. In order to solicit specific cognitive process, two tasks were used with two levels of difficulty. In one task, the variable compatibility was manipulated. In the other task, the foreperiod duration varied «1150 msec. vs >5500 msec.). The two tasks and the four conditions were randomly presented and each warning signal appeared 1200 msec. after the preceding response. Errors and response time were recorded continuously by the computer.

For every subject, the experiment was conducted in three separate sessions. In any case, the sessions took place at the same time of the day. During the first session (A) subjects were familiarized with RT tasks (to determine individual standards of performance, Sanders, 1990) and with physical protocol (to determine individual self-paced pedalling rate). The RT tasks were assessed at rest (session B) or concurrent I y with the pedalling task, whose relative power was corresponding to 60% Pmax., from the third minute of exercise (session C). The order of the sessions Band C varied systematically between subjects.
RESULTS

The validity of the experimental protocol was dependent on the reproducibility of physiological parameters, collected at rest and during each pedalling task. The analysis of heart rate (HR, in batt.min\(^{-1}\)) during compatibility and foreperiod tasks (74.86 vs 73.24) showed no significant difference between these two modalities, and likewise between the levels of difficulty. Results were similar for HR collected during pedalling tasks (145.33 vs 146.77). Besides, when these last data were expressed in relative values (% HRmax.) they showed that during pedalling tasks (62.19 vs 61.65) exertion was strictly aerobic and respected criterion of reproducibility determined in same protocol (Becque, Katch, Marcqts & Dayeur, 1993).

The analysis of individual mean RT performance, collected at rest for two levels of difficulty showed a significant decrement for compatibility (F\(_{1,23}=198.10, p<.0000\)) and foreperiod duration (F\(_{1,23}=75.16, p<.0000\)) tasks. Similar results were observed on the first and the third quartiles of mean RT in the compatibility task, respectively (F\(_{1,23}=95.94, p<.0000\)) and (F\(_{1,23}=194.52, p<.0000\)). In the same way, on the first and the third quartiles of mean RT in the foreperiod task, respectively (F\(_{1,23}=86.66, p<.0000\)) and (F\(_{1,23}=29.93, p<.0000\)).

The effect of physical effort on error rate was analysed for each subject and each level of difficulty, by two-way analysis of variance (exertion x levels of difficulty) with repeated measurements on both factors. The analysis indicated no main effect of exertion on error rate for the two cognitive tasks and no interaction between factors. Thus, the assumption of Additive Factors Method should be applied.

Mean RT data are reported in table 1. Data were submitted to a two-way analysis of variance similar to the one performed on error rate. Results indicated a significant main effect of exertion, both for the compatibility variable (F\(_{1,23}=25.48, p<.0000\)) and for foreperiod duration variable (F\(_{1,23}=22.73, p<.0001\)). Choice RT was significantly improved. Besides, no interaction effect between exertion and cognitive variables was found.

TABLE 1: Mean RT Performances (msec.) According to Exertion (Standard Deviation in Brackets)

<table>
<thead>
<tr>
<th></th>
<th>Rest</th>
<th>Exertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compalibility</td>
<td>258.07</td>
<td>241.88***</td>
</tr>
<tr>
<td></td>
<td>(16.67)</td>
<td>(15.76)</td>
</tr>
<tr>
<td>No Compalibility</td>
<td>309.24</td>
<td>289.73***</td>
</tr>
<tr>
<td></td>
<td>(21.12)</td>
<td>(27.10)</td>
</tr>
<tr>
<td>Short foreperiod</td>
<td>254.43</td>
<td>242.50***</td>
</tr>
<tr>
<td></td>
<td>(17.10)</td>
<td>(25.75)</td>
</tr>
<tr>
<td>Long foreperiod</td>
<td>280.03</td>
<td>261.92***</td>
</tr>
<tr>
<td></td>
<td>(21.66)</td>
<td>(24.21)</td>
</tr>
</tbody>
</table>

Note: The difference between RT performances at rest and during exertion was significant at *p<.05, **p<.025 and ***p<.001.

The first and third quartiles of mean RT data were submitted to a similar analysis.
The analysis of the first quartiles values indicated a significant main effect of exertion, both for the compatibility variable \(F(1,23=21,10, p<.0001)\) and for the foreperiod variable \(F(1,23=23,68, p<.0001)\). These data showed essentially the same results as obtained with the mean RT. Next, no interaction effect between exertion and cognitive variables was found.

Similar results for main effects were obtained when using the third quartiles of mean RT data as dependent variable. They were reported in table 2. The analysis confirmed a significant improvement of RT performance by exertion, both on the compatibility \(F(1,23=21,52, p<.0001)\) and the foreperiod \(F(1,23=21,85, p<.0001)\) variables. Besides, no interaction effect between exertion and compatibility was found.

**TABLE 2 : Third Quartiles of Mean RT Performances (msec.) According to Exertion (Standard Deviation in Brackets)**

<table>
<thead>
<tr>
<th></th>
<th>Rest</th>
<th>Exertion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compatibility</td>
<td>277.68</td>
<td>261.44***</td>
</tr>
<tr>
<td></td>
<td>(18.68)</td>
<td>(15.62)</td>
</tr>
<tr>
<td>No Compatibility</td>
<td>337.57</td>
<td>317.92***</td>
</tr>
<tr>
<td></td>
<td>(27.15)</td>
<td>(29.15)</td>
</tr>
<tr>
<td>Short Foreperiod</td>
<td>272.10</td>
<td>262.65***#</td>
</tr>
<tr>
<td></td>
<td>(17.96)</td>
<td>(26.34)</td>
</tr>
<tr>
<td>Long Foreperiod</td>
<td>297.75</td>
<td>276.54***#</td>
</tr>
<tr>
<td></td>
<td>(28.06)</td>
<td>(26.80)</td>
</tr>
</tbody>
</table>

Note: The difference between RT performances at rest and during exertion was significant at *p<.05, **p<.025 and ***p<.01. The interaction (exertion- level of difficulty) was significant at #p<.05.

A *contrario* of the previous results, the analysis indicated a significant effect of interaction between exertion and foreperiod duration \(F(1,23=4.85, p<.0315)\). Compared with the RT performance at rest, post-hoc analysis (Newmann Keuls test) indicated a significant improvement of RT performance during exercise, for the two levels of difficulty, more especially on long foreperiod duration.

**DISCUSSION**

The effects of exertion on choice reaction time were quite consistent with those obtained in previous works (Brisswalter, Legros & Delignières, 1994; Delignières, Brisswalter et Legros, 1994; Delignières & Brisswalter, this volume).

Nevertheless, in these preceding studies, the improvement in performance by physical exertion concerned only the experts in decisional tasks. One of the most striking results of this experiment consisted in the possibility to obtain an improvement of RT performance, during physical exercise, even with subjects that did not possess this kind of expertise. This finding make complete the interpretation which explain the differentiated effect of exertion on simple and choice RT paradigms solely for experts in decisional activities (Delignières, Brisswalter & Legros, 1994 ; Durand, Bourrier & Legros, 1991).
According to Additive Factors Method assumption, an interaction obtained between exertion and foreperiod duration suggested that the variables interfere with the same cognitive process: motor adjustment. The hypothesis of differentiated effect of exertion on the sequence of information processing was confirmed because only a significant interaction was revealed on foreperiod duration variable, especially when thirds quartiles values were dependent variable. This result confirmed that the effect of exertion fluctuated widely between individual trials and that it affected on particular the end of RT distribution (Sanders, 83).

This selective effect of exertion on cognitive processes was in accordance with the Sanders' predictive cognitive-energetical model (1983), which postulated complex influences of specific energetical supplies on each information processing stage.

In accordance with previous works of Pribram and McGuinness (1975) the mutual relations between physical exertion and cognitive processes should be interpreted by a direct influence of activation on the motor side of information processing sequence. Another studies should appear necessary in the aim of validating these results and exploring more widely the locus of influence of physical exertion on cognitive process.

REFERENCES


